

# **Economic Analysis for the Water Storage and Investment Program**

## **Unit Values Estimation**

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# Contents

## **Introduction 1**

Organization of This Document.....	1
<b>Chapter 2 Municipal and Industrial Water Supply Reliability Benefits.....</b>	<b>2</b>
Water Transfer Pricing Estimation Method.....	3
Benefit Estimation Procedures.....	5
Water Supply .....	5
Geographic Location.....	5
Real Water Price Escalation.....	5
Buyer Type.....	5
Seller Type .....	6
Drought Water Bank and Environmental Water Account .....	6
Results6	
Equation 1 Discussion.....	8
Equation 2 Discussion.....	10
Future Water Market Prices .....	10
Estimated Conveyance Charges.....	11
Estimated Conveyance Losses .....	12
<b>Chapter 3 Refuge Water Supply Benefits.....</b>	<b>14</b>
Market Price for Water to Refuges .....	14
<b>Chapter 4 Agricultural Water Supply Benefits .....</b>	<b>18</b>
Market Price for Water to Agriculture.....	18
<b>Chapter 5 Summary of Estimated Unit Values.....</b>	<b>1</b>
<b>Chapter 6 References.....</b>	<b>1</b>

# Introduction

This document provides supporting information on the inputs and analyses used to estimate various unit values for the water supply benefits for projects that are applying for funding from the Water Storage Investment Program (WSIP). The unit values are estimated for a variety of benefit categories, end user locations, and timeframes to support the economic feasibility requirements for WSIP applications. The water supply benefit categories included in this document are Municipal and Industrial (M&I), Refuge, and Agriculture. All unit values are estimated through the application of an economic model that estimates the costs of water acquired on the spot market. Unit values are estimated for 2015, 2030, and 2045. Due to the uncertainty associated with long-term projections, unit values are not estimated for 2070.

## Organization of This Document

This document is organized as follows:

**Chapter 1, Introduction**, provides an overview of the purpose of this appendix.

**Chapter 2, Municipal and Industrial Water Supply Reliability**, describes methods used to estimate unit values associated with M&I water supply reliability.

**Chapter 3, Refuge Water Supply Reliability Benefits**, describes refuge water supply reliability benefits.

**Chapter 4, Agricultural Water Supply Reliability Benefits**, describes emergency water supply benefits.

**Chapter 5, Summary of Estimated Unit Values**, provides a summary of estimated unit values by end use category, location, and year type.

**Chapter 6, References**, contains sources of information used to prepare the appendix.

## Chapter 2

# Municipal and Industrial Water Supply Reliability Benefits

In this analysis, the benefits to M&I water users are measured according to the cost of the most likely alternative water supply that would be pursued in the absence of development of the proposed projects. For water supply reliability benefits, the cost of the most likely alternative represents the next unit of water supply the water user would purchase, or develop, if the project under consideration were not in place. The cost of the most likely alternative assumes that if the preferred alternative is not implemented, the alternative action most likely to take place provides a relevant comparison. This valuation approach relies upon the costs associated with observed market transactions for water. As a result, the resulting estimates may underestimate willingness to pay.

M&I water users rely on the water transfer market to augment existing supplies and avoid shortages. For example, Bay Area water providers purchased more than 40,000 acre-feet (AF) during 2015 at unit prices between \$300 and \$700 per AF (not including conveyance costs). In addition, water market purchases are included as part of the long-term water supply portfolio for many water providers in the region. This analysis relies in part on market prices paid to purchase water on an annual basis from willing sellers. The market prices are reported according to the payments made directly to the sellers. The buyers incur additional costs to convey the water to their M&I service areas. These costs include both conveyance losses, which diminish the volume of water delivered to end users, as well as wheeling and power charges. Conveyance losses are incorporated into the adjusted water market price by dividing the estimated water market price paid to sellers by the proportion of acquired water that is delivered to the end use. The conveyance costs are estimated for M&I water users benefiting from the alternative plans, and added to the estimated market prices to acquire the water to develop an estimate of the full cost associated with additional water supply obtained in the transfer market. Figure 1 illustrates the information used to estimate the value of M&I water supplies.



Figure 1. General M&I Water Value Estimation Procedures

## Water Transfer Pricing Estimation Method

A database of California surface water market sales was developed for use in estimation of the water transfer pricing model. Information for each transaction was researched and recorded to allow statistical analysis of a variety of factors influencing water trading activity and prices. During the research, transactions occurring from 1990 through 2016 were documented. The transactions were filtered for this analysis according to the following criteria:

- Water sales originating outside the operating region of the SWP facilities were excluded. These regions include the North Coast, North Lahontan, and South Lahontan regions.
- The water transfer pricing model, which relies upon the database of water transactions described above, is intended to estimate spot market prices and trading activity. Thus, multi-year transfers and permanent water entitlement sales were excluded.
- “Within-project” transfers were removed from the analysis, because they do not reflect “arms-length” transactions, whereby buyers and sellers are separate parties acting in their individual interests.
- Transactions associated with SWP Turnback Pool supplies were excluded because they are associated with rules that limit market participation.
- Purchases of “flood” supplies (e.g. SWP Article 21 and CVP 215) were excluded as prices are administratively set and do not have comparable reliability to the water supply from the proposed projects.
- Reclaimed and desalination water sales were removed from the analysis because they represent cost rather than market-based supplies.
- Leases of groundwater pumping allocations within adjudicated groundwater basins were excluded because they take place within isolated markets with different regulatory conditions from the market for surface water.
- Water sales with incomplete or inadequate information were excluded.

From 1990 through 2016, the database contains information on approximately 6,000 spot market (single year) transactions. Many of these involve groundwater leases within adjudicated basins. Following application of the above criteria, 678 spot market transfers remained to support the statistical analysis. All prices were adjusted to July 2015 dollars using the Consumer Price Index. As previously described, prices and volumes are presented from the seller’s perspective and do not include conveyance charges or losses.

Although Federal and State government agencies have recently been more active in recording some information related to water sales or leases, California has few sources that track water transfers between private individuals. Most of the recorded transfers involve a Federal or State government party either because an agency had to approve the transfer, as is the case when a transfer involves CVP or SWP water, or because the government agency was directly involved in the transfer as a purchaser or a seller. Transfers involving private parties are more difficult to track, because the State does not have any reporting requirements.

In California, single-year transfers of water entitlements issued before 1914 are allowed without review by the State Water Resources Control Board (State Water Board) as long as they do not adversely impact the water rights of a third party (CALFED, 2000). For entitlements issued after 1914, the buyer and seller can petition the State Water Board for a 1-year temporary transfer. Nonetheless, prices for these transfers are not well documented. As a result, the data for this study were obtained from a mixture of public and private sources. Public sources include the following:

- Water Acquisition Program (WAP), Reclamation
- Resources Management Division, Environmental Water Account (EWA)
- State Water Bank, DWR
- OnTap database, DWR
- State Water Board, California Environmental Protection Agency (Cal/EPA)
- Various irrigation districts and water agencies

These sources provided information on the WAP, EWA, State Water Bank, and other public water transfers. State Water Bank observations included transfers to the State Water Bank to capture the price the seller receives.

Information on water transfers was also obtained from the January 1990 through December 2010 issues of the *Water Strategist*. The publication, previously called *Water Intelligence Monthly*, assembles information on public and private water transfers. Although not all transfers are recorded in the *Water Strategist*, the publication represents a primary source for water market research. Many of the transfers reported in the *Water Strategist* were independently researched to obtain more specific information and confirm transaction terms. *The Water Strategist* ceased to report on transactions in 2010. In addition, transactions not covered by the *Water Strategist* were researched and verified through direct communication with the transfer participants.

## **Benefit Estimation Procedures**

This study applies a water transfer pricing regression model and builds on a previous analysis completed by Mann and Hatchett (2006) by applying an expanded data set and considering additional factors that influence water market trading activity and prices. Unlike the Mann and Hatchett analysis, which estimated a recursive regression model using Ordinary Least Squares techniques, the water transfer pricing model developed in this study is non-recursive, using Two-Stage Least-Squares. The first equation estimates the unit price for spot market water transfers, and the second estimates annual spot market trading activity. The coefficients from the models may be used to forecast future water prices north of Delta (NOD) and south of Delta (SOD).

The regression model theorizes that prices and volume of water traded can be estimated through consideration of the following market factors: water supply, geographic location, real water price escalation, buyer type, and State and Federal water supply acquisition programs.<sup>1</sup> These factors are described below.

### **Water Supply**

As previously described, hydrologic conditions are a primary driver of water transfer market activity and prices. Therefore, it is important to include variables that appropriately capture water supply conditions to describe water trading activity and prices. In this analysis, water supply conditions are measured using the final annual SWP allocation (DWR, 2017a), the final CVP allocation (Reclamation, 2017), and the Sacramento River Water Year Index (DWR, 2017b).

### **Geographic Location**

Water prices and trading activity vary by location according to water year type. Consequently, the origin of the water source for each transaction is used to determine geographic differences in water prices. Water sales applied in the regression analysis were allocated among the hydrologic regions identified by DWR (DWR and Reclamation, 2006). Binary variables are used to denote the different geographic regions of buyers and sellers including a variable identifying spot market transfers that involved through-Delta conveyance.

### **Real Water Price Escalation**

Due to the growing urban water demand in the State, water transfer prices are anticipated to increase over time. To test for hypothesized price appreciation, the model includes an independent variable taking on the value of the year in which the transfer occurred.

### **Buyer Type**

Previous economic analyses of water prices have concluded that the type of buyer (e.g., M&I, agricultural, and environmental) influences water prices. The water pricing equation tests the influence of buyer type on water price and trading. In

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<sup>1</sup> Additional demand and supply factors were tested in the model but did not result in an improvement in overall explanatory power.

this analysis, binary variables are used to estimate price differences among environmental, urban, and agricultural buyers.

### **Seller Type**

CVP and SWP agricultural contractors are the most common water sellers in the spot market. In order to test the influence of the two projects on water prices, a binary variable identifying sellers that are SWP contractors is included in the model.

### **Drought Water Bank and Environmental Water Account**

The State has participated in the water market during drought years to facilitate trades. Under this program, DWR sets up a State Water Bank to facilitate water transfers, primarily from NOD agricultural users to SOD buyers. To account for the market conditions that existed during operation of the State Water Bank.

The EWA acquired water supplies for environmental purposes annually between 2001 and 2007. The implementation of the EWA impacted spot market trading and prices by introducing a large, new demand for water supplies. A dummy variable separating acquisitions by the EWA from other buyers is included to test for the price impacts of the program. A binary variable is included in the model to test the influence of the two programs on prices and trading activity.

## **Results**

Two equations are constructed to estimate the economic benefits of increased M&I water supplies. The first equation forecasts water transfer prices based on hydrologic conditions, price appreciation over time, water supplier region, buyer type, buyer location, and premiums associated with DWR Drought Water Bank and EWA transactions. Information on 678 spot market water transfers is included in the data, allowing the model to forecast spot-market prices.

The second equation predicts the total annual volume of water traded in the spot market. Total annual trading volume is calculated using 678 spot market transfers, and is reported in thousands of acre-feet. The trading volume equation projects total annual volume traded based on hydrologic conditions, environmental water acquisition programs, and water transfer prices predicted by the first equation. The predicted water transfer prices obtained from Equation 1 are used as the explanatory price variable *lnadjpricehat* in Equation 2. Each equation's specification and variables are defined, and the Two-Stage Least-Squares regression results are presented in Table 1.

## Equation 1

$$\ln adjprice = scbuyer + nodbuyer + nodsod + \ln year + \ln twpper + ag + env + dwbewa + swpseller + e$$

*lnadjprice* = Natural logarithm of price per acre-foot, adjusted to July 2015 dollars

*scbuyer* = 1 if South Coast Region Water Buyer (binary)

*nodbuyer* = 1 if the Buyer is North of the Delta (binary)

*nodsod* = 1 if North of Delta Water Supplier and South of the Delta buyer (binary)

*lnyear* = Natural log of the year in which the transfer occurred

*ln twpper* = Natural log of the percentage of Project water that was allocated in the year of the transfer

*ag* = 1 if Agricultural end users (binary)

*env* = 1 if Environmental (refuge) end user (binary)

*dwbewa* = 1 if State Water Bank/Dry Year Water Acquisitions or the Environmental Water Account (binary)

*swpseller* = 1 if the seller was a State Water Project contractor (binary)

*e* = Error Term

## Equation 2

$$\ln spottaft = drycrit + \ln adjpricehat + ewayear + e$$

*lnspottaft* = Natural logarithm of total acre-feet traded annually (thousands)

*drycrit* = 1 if a dry or critical year as indicated by the Sacramento River Water Year Index (binary)

*lnadjpricehat* = Values of the variable *lnadjprice* predicted by Equation 1

*ewayear* = 1 if year in which the EWA operated (binary)

*e* = Error Term

Table 1. Regression Results

Equation <sup>1</sup> Dependent Variables	Observations	Parameters	RMSE	R-Squared	F-Statistic	P-Value (P > F)
<i>lnadjprice</i>	678	9	0.35	0.34	130.01	0
<i>lnspottaft</i>	678	3	0.56	0.64	120.34	0
<b>Stage 1: Dependent Variable <i>lnadjprice</i></b>						
Independent Variables	Coefficient	Standard Error	t- Statistic	P-Value (P >  t )	95% Confidence Interval	
<i>scbuyer</i>	0.25	0.09	2.71	0.01	0.07	0.44
<i>nodbuyer</i>	-0.35	0.08	-4.52	0.00	-0.51	-0.20
<i>nodtosod</i>	-0.16	0.07	2.28	0.02	-0.29	-0.02
<i>lnyear</i>	117.97	6.73	17.54	0.00	104.79	131.16
<i>lnwpper</i>	-0.79	0.08	-9.98	0.00	-0.94	-0.63
<i>ag</i>	-0.15	0.06	-2.54	0.01	-0.27	-0.04
<i>env</i>	-0.30	0.08	-3.57	0.00	-0.46	-0.13
<i>dwbewa</i>	0.29	0.06	4.77	0.00	0.17	0.40
<i>swpseller</i>	0.55	0.07	8.49	0.00	0.42	0.68
<i>cons</i>	-892.28	51.13	-17.45	0.00	-992.48	-792.07
<b>Stage 2: Dependent Variable <i>lnspottaft</i></b>						
Independent Variables	Coefficient	Standard Error	t- Statistic	P-Value (P >  t )	95% Confidence Interval	
<i>drycrit</i>	0.47	0.03	16.39	0.00	0.41	0.52
<i>lnadjpricehat</i>	-0.06	0.02	-3.23	0.00	-0.09	-0.02
<i>ewayear</i>	0.38	0.04	9.78	0.00	0.30	0.45
<i>cons</i>	5.75	0.11	53.64	0.00	5.54	5.96

Note:

<sup>1</sup> Equations and variables are defined in Equations 1 and 2 above.

Key:

RMSE = root-mean-square error

All estimated relationships between dependent and independent variables are statistically significant at the 99 percent confidence level. The quality of the two-stage least squares modeling results are dependent upon the results of the first stage estimation.

### Equation 1 Discussion

The variable *lnwpper* is a measure of annual water availability. The amount of water available was calculated using the SWP and CVP maximum contract amounts, and the percentage of the maximum contract that was delivered each year to the different contractors. The SWP and CVP allocations decrease during drought conditions. Regulatory actions such as the Delta pumping constraints could further impact water deliveries. The statistical relationship between *lnadjprice* and *lnwpper* is attributable to increased demand for additional water supplies under the hydrologic and regulatory scarcity conditions that drive reduced water allocations. As an example, the coefficient value of -0.7872 on the *lnwpper* variable indicates that water transfer prices increase by approximately 50 percent in response to a decrease in percentage of total project water allocation from 50 percent to 30 percent, all else held equal.

The coefficient value on the variable *lntyear* indicates that water transfer prices rose at a real annual rate of approximately 6 percent between 1990 and 2016.<sup>2</sup>

The binary variables in the price equation describe conditions that influence prices, but are qualitative in nature. The coefficients for *env* and *ag* represent the influence that end-water use has on price. When these variables are zero, the model estimates prices to urban water users. Agricultural and environmental water users generally paid less for water than urban users, as indicated by the negative coefficients on the two variables. The results show environmental water buyers have paid 26 percent less per acre-foot than urban buyers in the market, with all else being equal. Similarly, water leases for agricultural use were priced 14 percent per acre-foot less than urban water leases, with all else being equal. These results may reflect the relative budget constraints among the three buyer categories.

The variable *dwbewa* is an indicator that the lease was either a State water lease through the Drought Water Bank of 1991, 1992, 1994, and 2009, or a lease through the EWA program. The binary variable is used to account for the price premium that occurred during operation of the bank and the EWA program. The coefficient value indicates that water leased during the operation of the Drought Water Bank, and water that was purchased through the EWA program, was priced 33 percent higher than other transactions, with all else being equal.

The variable *nodbuyer* is a binary variable measuring the difference in spot market prices between water originating and remaining NOD, compared to water that originated SOD. Sales from NOD suppliers to NOD buyers were 30 percent lower than sales originating SOD, suggesting there is a higher value for water SOD.

The variable *nodtosod* is a binary variable that captures the difference in spot market prices between water transactions where the water originated NOD and was transferred SOD, compared to water that originated SOD. NOD to SOD sales were priced 15 percent lower than sales where water originated SOD. This discount is attributable to water losses and other challenges that occur for supplies conveyed through the Delta.

According to the coefficient estimated for *scbuyer*, water transactions involving buyers in the South Coast region were priced 29 percent higher than acquisitions by buyers in other regions, with all else being equal. Premium prices paid by South Coast buyers result from strong competition for water supplies in the region, and the relatively high-value water uses in the area.

The variable *swpseller* is a binary variable measuring the premium paid for purchasing SWP water. The coefficient on *swpseller* indicates SWP sellers

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<sup>2</sup> Example Calculation:  $2.71828^{(116.392 \cdot \ln(\text{Year}_T))} = A$ ;  $2.71828^{(116.392 \cdot (\ln(\text{Year}_{T-1}))} = B$ ;  $(A-B)/B = 6\%$ .

receive a premium of approximately 74 percent over CVP and non-project sellers, on average.

### Equation 2 Discussion

The California water transfer market is governed by a complex set of legal, institutional, and physical conditions and is not an efficient (perfectly competitive) market. However, the successful estimation of the demand function (Equation 2) supports the use of water transfer prices for quantifying NED municipal and industrial water supply reliability benefits. The ability to estimate demand as a function of price in California's water transfer market confirms that the market is active and, through prices, provides to both sellers and buyers the marginal value of water in its higher-valued uses (Brookshire et al. 2004). Thus, forecasted water transfer prices estimated by the model (Equation 1) represent an appropriate measure of NED municipal and industrial water supply reliability benefits.

Equation 2 estimates total annual water market activity in spot market transfers according to hydrologic conditions, demand, and the current range of water transfer prices.

The dependent variable in the second equation, *lnspottaft*, is measured as the natural logarithm of the total annual volume of water (in TAF) traded in regions within the SWP service area through the recorded spot market water transfers beginning in 1990. As expected, the level of market activity holds an inverse relationship with water transfer prices (*lnadjpricehat*), indicating a down-sloping demand curve. Under the same hydrologic and demand conditions, more water trading occurs as prices drop.

Several different proxies for physical water scarcity conditions were tested, including annual CVP allocations, the Sacramento River Water Year Index, and a binary variable separating dry and critically dry years from wetter years. The selected variable *drycrit* held the strongest statistical relationship with *lnspottaft*.

The binary variable *ewayear* estimates the impacts of environmental water acquisition programs on trading activity. The positive coefficients on each variable demonstrate that environmental water acquisition programs shift the water market demand curve out, resulting in a larger volume traded, with all else being equal.

## Future Water Market Prices

In this section, the model is used to estimate water prices for 2015, 2030, and 2045 by geographic region and hydrologic condition. Table 2 provides estimated water market prices for M&I water acquisitions for the selected years and regions. NOD and SOD were selected as supplier regions used to estimate the value of the increased water supply. For SBA water providers during wet and above-normal

water years, the analysis applies SOD prices to value increased M&I supplies due to conveyance limitations for NOD supplies. During below-normal, dry, and critical years, the analysis applies NOD prices due to increased capacity to move the relatively less expensive NOD water through the Delta. For EBMUD and Sacramento Valley, it was assumed that all purchased water would come from NOD.

Table 2. Estimated M&I Water Prices by Region (\$/AF)

Region	Year Type	2015	2030	2045
EBMUD	Wet	\$191	\$432	\$1,030
	Above Normal	\$202	\$457	\$1,089
	Below Normal	\$248	\$560	\$1,336
	Dry	\$256	\$580	\$1,384
	Critical	\$327	\$741	\$1,767
Sacramento Valley	Wet	\$191	\$432	\$1,030
	Above Normal	\$202	\$457	\$1,089
	Below Normal	\$248	\$560	\$1,336
	Dry	\$256	\$580	\$1,384
	Critical	\$327	\$741	\$1,767
South Bay	Wet	\$224	\$506	\$1,030
	Above Normal	\$236	\$535	\$1,089
	Below Normal	\$290	\$560	\$1,336
	Dry	\$300	\$580	\$1,384
	Critical	\$384	\$741	\$1,767

Notes:

Sacramento Valley Water Year Hydrologic Classification Index used to define water year types.

Dollar values are expressed in July 2015 price levels.

Estimated prices are for water transferred among parties located in different hydrologic regions.

Key:

Wet = Total SWP and CVP deliveries is 89% of contracted volume.

Above Normal = Total SWP and CVP deliveries is 83% of contracted volume.

Below Normal = Total SWP and CVP deliveries is 64% of contracted volume.

Dry = Total SWP and CVP deliveries is 61% of contracted volume.

Critical = Total SWP and CVP deliveries is 45% of contracted volume.

M&I = Municipal and industrial

NOD = Supplier located North of the Delta

SOD = Supplier located South of the Delta

## Estimated Conveyance Charges

This section summarizes the estimated water conveyance charges by buyer location. The power costs associated with conveying the water purchase on the spot market to the end user is added to the estimated water purchase price described above. The cost to convey water to M&I users is estimated according

to the cost to move water through SWP facilities. Conveyance cost varies by location and user type. For example, SWP contractors pay a unit variable cost to move water based on a melded power rate. In comparison, non-SWP contractors pay a wheeling charge for access to SWP facilities, in addition to a market rate for the power required to pump the water. This analysis applies a wheeling charge of \$110/AF for water delivered to EBMUD through the Freeport facility.<sup>3</sup> Water delivered to the SBA is charged a wheeling rate of \$63/AF.<sup>4</sup> Water delivered to the Sacramento Valley is charged \$30.51/AF based upon the conveyance costs associated with recent CVP water transfers.

## Estimated Conveyance Losses

It is necessary to estimate conveyance losses to adjust estimated water market prices according to the geographic source of the supply. For example, an estimated delivery of 1,000 acre-feet to an M&I user may require the purchase of 1,111 acre-feet at the source, if 10 percent conveyance losses apply. Due to limited information regarding conveyance losses and specific sources of the transfer water, this analysis applies a 25 percent conveyance loss to water originating NOD and delivered to the South Bay Aqueduct.<sup>5</sup> Conveyance losses for water supplies to the South Bay Aqueduct originating SOD are assumed to be 10 percent. Water delivered to EBMUD through the Freeport Facility is assessed a 15 percent loss.<sup>6</sup> Conveyance losses are not applied to water purchases in the Sacramento Valley.

Combined water market prices, carriage losses, and conveyance costs are provided in Table 3. The values reflect the total cost of water (water price + conveyance losses + conveyance charges) to M&I water user by location and year type in 2015, 2030, and 2045. For the purposes, of the Nevada Irrigation District's (NID) proposed project, Centennial Reservoir, unit values for the Sacramento Valley were used.

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<sup>3</sup> Personal communication with Senior Civil Engineer with Water Supply Improvements Division at EBMUD.

<sup>4</sup> This is the average wheeling rate for non-SWP water delivered using the SBA.

<sup>5</sup> This includes an estimated 20 percent conveyance loss for through-Delta transfers and a 5 percent conveyance loss assigned to non-project water supplies conveyed through SOD canals. It should be noted that conveyance losses (or carriage water) vary according to a variety of factors including conditions in the Delta and water source. For example, through Delta conveyance losses have ranged from 20 percent to 30 percent from 2009 through 2013. The conveyance losses applied here are intended to reflect the average across all conditions. Source: Personal communication with Supervisory Engineer (Bureau of Reclamation) and Chief of Water Management Branch (DWR).

<sup>6</sup> Personal communication with Senior Civil Engineer from Water Supply Improvements Division at EBMUD.

Table 3. Estimated M&I Water Supply Unit Values (\$/AF)

<b>Region</b>	<b>Year Type</b>	<b>2015</b>	<b>2030</b>	<b>2045</b>
EBMUD	Wet	\$354	\$638	\$1,342
	Above Normal	\$367	\$667	\$1,411
	Below Normal	\$421	\$789	\$1,702
	Dry	\$431	\$812	\$1,757
	Critical	\$515	\$1,001	\$2,208
Sacramento Valley	Wet	\$221	\$463	\$1,061
	Above Normal	\$232	\$487	\$1,120
	Below Normal	\$278	\$591	\$1,367
	Dry	\$287	\$611	\$1,414
	Critical	\$358	\$772	\$1,797
South Bay	Wet	\$335	\$649	\$1,231
	Above Normal	\$349	\$681	\$1,297
	Below Normal	\$491	\$851	\$1,886
	Dry	\$504	\$877	\$1,949
	Critical	\$615	\$1,092	\$2,460

# Chapter 3

## Refuge Water Supply Benefits

The 19 federal wildlife refuges in the Central Valley are part of the U.S. Wildlife Refuge system. Through the passage of the CVPIA in 1992, fish and wildlife were given equal priority as other water uses in the CVP service area. As a result, the federal government was required to provide a clean and reliable supply of water to wetland habitats in these refuges in support of fish and wildlife species. This is being accomplished through the Refuge Water Supply Program (Reclamation and USFWS 2009).

Reclamation delivers water to wildlife refuges in the Central Valley as a requirement of the CVPIA, as Level 2 supply (firm supply) and Incremental Level 4 supply (purchased from willing sellers). Currently, Incremental Level 4 refuge demands are not being fully met, and the new water supply developed by the proposed projects may be used to provide a more reliable supply to meet Level 4 refuge demands.

This section addresses the refuge water supply benefits that may be realized by providing additional refuge water supplies to help meet Incremental Level 4 refuge water needs. The approach to estimate refuge water supply benefits considers the estimated short-term market purchase price as the most likely alternative in the absence of firm water supply from the proposed projects. In addition, to address risk and uncertainty, a sensitivity analysis that addresses the habitat production value of additional water in terms of increased willingness to pay by recreation visitors to affected refuges.

### Market Price for Water to Refuges

Historically, Incremental Level 4 water supplies have been primarily obtained through water lease agreements. In this analysis, the benefits of refuge water supply associated with the proposed projects are measured according to the estimated cost of obtaining the water supply through continued spot market leases. The water transfer pricing model described in Chapter 2 is applied here to estimate the benefits of improved refuge water supply. As previously described, the economic model consists of a statistical analysis of documented spot market water transactions in California. The model seeks to explain the factors that influence California water market prices and is used to estimate 2015, 2030, and 2045 prices under a variety of conditions including seller and buyer location, buyer type, and hydrologic conditions.

Table 4 provides the estimated water market prices assuming:

- The water is being leased for environmental (refuge) purposes. As shown by the coefficient value for model variable *env* (presented in Table 1,

above), environmental buyers are typically able to acquire water for a lower price than urban buyers.

- Water is leased from lower priced NOD sources during below normal, dry, and critical years when Delta conveyance capacity is available. During above normal and wet year types water is leased from SOD sources.
- A 25 percent conveyance loss factor is applied to water leased from NOD sources and 10 percent to water leased from SOD sources.

Table 4. Estimated Refuge Water Prices (\$/AF)

<b>Region</b>	<b>Year Type</b>	<b>2015</b>	<b>2030</b>	<b>2045</b>
Delta Mendota Canal	Wet	\$166	\$399	\$951
	Above Normal	\$176	\$422	\$1,006
	Below Normal	\$184	\$442	\$1,053
	Dry	\$191	\$458	\$1,091
	Critical	\$244	\$584	\$1,393
California Aqueduct	Wet	\$166	\$399	\$951
	Above Normal	\$176	\$422	\$1,006
	Below Normal	\$184	\$442	\$1,053
	Dry	\$191	\$458	\$1,091
	Critical	\$244	\$584	\$1,393

In addition to the market price for water, buyers incur conveyance costs that vary with location and infrastructure. This analysis assumes that the refuge water delivered to the California Aqueduct is conveyed to the Dos Amigos Pumping Plant at a cost of approximately \$30/AF. The power cost for refuge water delivered to the Delta Mendota Canal is estimated at the Banks Pumping Plant and is approximately \$20/AF<sup>7</sup>. Combined water market prices, carriage losses, and conveyance costs for refuge water supplies are provided in Table 5. The values reflect the total cost of water (water price + conveyance losses + conveyance charges) to refuge water users by location and year type.

<sup>7 7</sup> Sources: California Department of Water Resources, Management of the California State Water Project: Bulletin 132-12. Table 7. Kilowatt-Hour Per Acre-Foot Factors for Allocating Off-Aqueduct Power Facility Costs, 2012.

Jones, Jon. Charges for Wheeling Non-State Water Project Water Through State Water Project Facilities, State Water Project Analysis Office Division of Operations and Maintenance, January 17, 2012.

Table 5. Estimated Refuge Water Supply Unit Values (\$/AF)

<b>Region</b>	<b>Year Type</b>	<b>2015</b>	<b>2030</b>	<b>2045</b>
Delta Mendota Canal	Wet	\$207	\$466	\$1,079
	Above Normal	\$218	\$491	\$1,140
	Below Normal	\$272	\$616	\$1,431
	Dry	\$281	\$637	\$1,481
	Critical	\$351	\$806	\$1,883
California Aqueduct	Wet	\$218	\$477	\$1,090
	Above Normal	\$229	\$502	\$1,151
	Below Normal	\$286	\$629	\$1,444
	Dry	\$294	\$650	\$1,494
	Critical	\$365	\$819	\$1,897

## Chapter 4

# Agricultural Water Supply Benefits

The proposed projects have the potential to improve water supply reliability for agricultural producers. Due to increased plantings of permanent crops and limited groundwater availability, agricultural producers in the region have consistently purchased water from other entities to satisfy crop water demands. For example, the San Luis Delta and Mendota Water Authority (SLDMWA) entered into a multiple-year agreement to purchase up to 60 TAF annually from the San Joaquin Exchange Contractors. SLDMWA and Tehama Colusa Canal have also purchased water from Sacramento Valley sources in recent years on the spot market. The additional water supply from proposed projects has the potential to benefit agricultural producers by offsetting a portion of future water purchase costs.

The approach to estimate agricultural water supply benefits considers the estimated short-term market purchase price as the most likely alternative in the absence of firm water supply from the proposed projects.

## Market Price for Water to Agriculture

The water transfer pricing model described above is applied here to estimate the benefits of improved refuge water supply. As previously described, the economic model consists of a statistical analysis of documented spot market water transactions in California. The model seeks to explain the factors that influence California water market prices and is used to forecast prices under a variety of conditions including seller and buyer location, buyer type, and hydrologic conditions.

Table 6 provides the estimated water market prices assuming:

- The water is being leased for agricultural purposes. As shown by the coefficient value for model variable *ag* (presented in Table 1, above), agricultural buyers are typically able to acquire water for a lower price than urban buyers.
- For water delivered to the Delta Mendota Canal, water is leased from lower priced NOD sources during below normal, dry, and critical years when Delta conveyance capacity is available. During above normal and wet year types water is leased from SOD sources.
- A 25 percent conveyance loss factor is applied to water leased from NOD sources and 10 percent to water leased from SOD sources.

Table 6. Estimated Agricultural Water Prices (\$/AF)

Region	Year Type	2015	2030	2045
Sacramento Valley	Wet	\$164	\$393	\$936
	Above Normal	\$173	\$415	\$989
	Below Normal	\$212	\$509	\$1,214
	Dry	\$220	\$527	\$1,257
	Critical	\$281	\$673	\$1,605
Delta Mendota Canal	Wet	\$192	\$460	\$1,096
	Above Normal	\$203	\$486	\$1,159
	Below Normal	\$212	\$509	\$1,214
	Dry	\$220	\$527	\$1,257
	Critical	\$281	\$673	\$1,605

In addition to the market price for water, agricultural buyers incur conveyance costs that vary with location and infrastructure. This analysis assumes that the purchased water is conveyed to agricultural users at a cost of approximately \$30/AF. Combined water market prices, carriage losses, and conveyance costs for agricultural water supplies are provided in Table 7. The values reflect the total cost of water (water price + conveyance losses + conveyance charges) to agricultural water users by location and year type. For the purposes, of the NID's proposed project, Centennial Reservoir, unit values for the Sacramento Valley were used.

Table 7. Estimated Agricultural Water Unit Values (\$/AF)

Region	Year Type	2015	2030	2045
Sacramento Valley	Wet	\$194	\$423	\$966
	Above Normal	\$204	\$446	\$1,020
	Below Normal	\$243	\$540	\$1,244
	Dry	\$250	\$558	\$1,287
	Critical	\$311	\$704	\$1,635
Delta Mendota Canal	Wet	\$235	\$533	\$1,240
	Above Normal	\$247	\$563	\$1,310
	Below Normal	\$310	\$706	\$1,645
	Dry	\$320	\$730	\$1,702
	Critical	\$401	\$924	\$2,166



# Chapter 5

## Summary of Estimated Unit Values

This document presents estimates of the economic benefits associated with increased water supplies. The estimated unit values were developed using an economic model of water transfer costs. This approach is consistent with the alternative cost method identified in the Technical Reference (California Water Commission, 2016).

Table 8 provides a summary of the estimated unit values by end use, location, and year type. Unit values were estimated for 2015, 2030, and 2045. Unit values were not estimated for 2070 due to the uncertainty associated with estimating water values that far into the future.

Table 8. Summary of Estimated Unit Values (\$/AF)

End Use/Region	Year Type	2015	2030	2045
Municipal/EBMUD	Wet	\$354	\$638	\$1,342
	Above Normal	\$367	\$667	\$1,411
	Below Normal	\$421	\$789	\$1,702
	Dry	\$431	\$812	\$1,757
	Critical	\$515	\$1,001	\$2,208
Municipal/Sacramento Valley	Wet	\$221	\$463	\$1,061
	Above Normal	\$232	\$487	\$1,120
	Below Normal	\$278	\$591	\$1,367
	Dry	\$287	\$611	\$1,414
	Critical	\$358	\$772	\$1,797
Municipal/South Bay	Wet	\$335	\$649	\$1,231
	Above Normal	\$349	\$681	\$1,297
	Below Normal	\$491	\$851	\$1,886
	Dry	\$504	\$877	\$1,949
	Critical	\$615	\$1,092	\$2,460
Refuge/Delta Mendota Canal	Wet	\$207	\$466	\$1,079
	Above Normal	\$218	\$491	\$1,140
	Below Normal	\$272	\$616	\$1,431
	Dry	\$281	\$637	\$1,481
	Critical	\$351	\$806	\$1,883
Refuge/California Aqueduct	Wet	\$218	\$477	\$1,090
	Above Normal	\$229	\$502	\$1,151
	Below Normal	\$286	\$629	\$1,444

	Dry	\$294	\$650	\$1,494
	Critical	\$365	\$819	\$1,897
Agriculture/Sacramento Valley	Wet	\$194	\$423	\$966
	Above Normal	\$204	\$446	\$1,020
	Below Normal	\$243	\$540	\$1,244
	Dry	\$250	\$558	\$1,287
	Critical	\$311	\$704	\$1,635
Agriculture/Delta Mendota Canal	Wet	\$235	\$533	\$1,240
	Above Normal	\$247	\$563	\$1,310
	Below Normal	\$310	\$706	\$1,645
	Dry	\$320	\$730	\$1,702
	Critical	\$401	\$924	\$1,605

# Chapter 6

## References

- Brookshire, D.S., B. Colby, M. Ewers, and P.T. Ganderton. 2004. Market Prices for Water in the Semiarid West of the United States. *Water Resources Research*, 40, W09S04, doi: 10.1029/2003WR002846.
- CALFED Bay-Delta Program (CALFED). 2000 Water Transfer Program Plan: Water Transfers Defined. Chapter 2. July.
- California Climate Change Center. 2009. Price Impact on the Demand for Water and Energy in California Residences. August.
- California Department of Water Resources (DWR). 2012. Management of the California State Water Project: Bulletin 132 12. Table 7. Kilowatt-Hour per Acre-Foot Factors for Allocating Off-Aqueduct Power Facility Costs.
- California Water Commission, 2016. Water Storage Investment Program Technical Reference.
- Jones, Jon. 2012. Charges for Wheeling Non-State Water Project Water Through State Water Project Facilities. State Water Project Analysis Office, Division of Operations and Maintenance. January 17.
- Mann, Roger, and Stephen Hatchett. 2006. Report on Environmental Water Account Water Price Estimation for the Common Assumptions Economic Workgroup. Prepared for California Department of Water Resources and United States Department of the Interior, Bureau of Reclamation.
- U.S. Department of the Interior, Bureau of Reclamation (Reclamation) and U.S. Fish and Wildlife Service (USFWS). 2009. Undelivered Water: Fulfilling the CVPIA Promise. Central Valley Project Improvement Act. Refuge Water Supply Program. Report of the Independent Review Panel. November.
- U.S. Department of Interior, Bureau of Reclamation (Reclamation) 2017. Summary of Water Supply Allocations, 1990-2016.
- Water Strategist. January 1990–December 2010. Information on Water Transfers.